October 2004 Progress Report on the Laboratory for Laser Energetics
Inertial Confinement Fusion Program Activities

Physical Data Research Program (LLNL) Recognition: Dr. Thomas R. Boehly of LLE and Dr. Damien G. Hicks of LLNL were recently recognized by the LLNL Physics and Advanced Technologies Director's Office for the development of a laser-driven reshock technique[1] and its application to accurate measurements of the deuterium equation of state (EOS) using single and double shocks. The double-shock technique developed on OMEGA offers a substantial increase in precision over earlier measurements. Determining the density of a shocked material with a compressibility as large as hydrogen requires high-precision measurements of the primary observables. This is because fractional errors in the inferred compression ratio ρ/ρ_0 are $\rho/\rho_0 - 1$ times greater than fractional errors in the observables U_s (shock speed) and U_p (particle speed). Making a measurement precise enough to discriminate among the various deuterium EOS models presents a significant experimental challenge. The first experiment[2] to study deuterium under double-shock conditions at megabar pressures used shocks reflected from an aluminum anvil. It was recognized that the expected differences between EOS model predictions for the experimental observables are greater in the reflected-shock measurement than in a single-shock measurement. Reflected shocks thus provide a more-sensitive experimental platform for discriminating among the various models; they do, however, probe not only the principal Hugoniot but also the re-shock Hugoniots and thus are complementary, rather than equivalent probes of the equation of state.

In the LLE/LLNL experiment, fluid deuterium was shocked initially to 0.7 to 2.5 Mbar and then double shocked to 2.5 to 9 Mbar; thus a wider range of pressure was covered, and the precision of these experiments was improved by using α-quartz—a transparent re-shock anvil material—rather than aluminum. This allows the use of a high-precision, line-imaging optical interferometer to record the shock-front velocity continuously as it transits the deuterium–quartz interface. Such an approach also minimizes any systematic errors due to shock unsteadiness and nonplanarity since the measurements are localized to essentially one point in space and time (see Figs. 1 and 2).

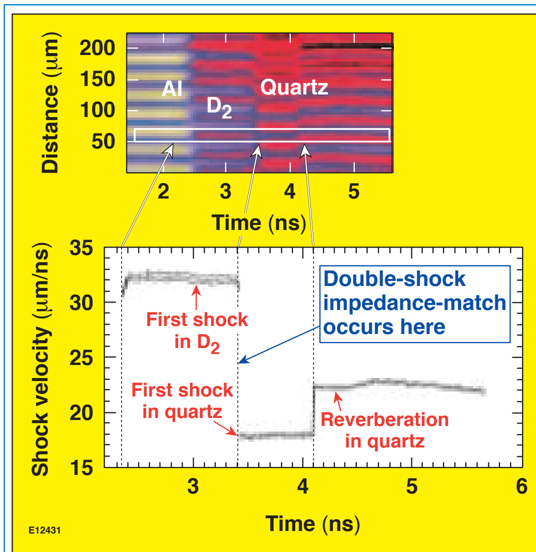

Figure 1. (a) Sample VISAR trace showing the signal from the reflecting shock front in deuterium and quartz. (b) Resulting velocity profile extracted from the VISAR trace in (a). Dotted lines above and below the main trace indicate the error at each time step. The shock traverses the deuterium–quartz interface at time t_x.

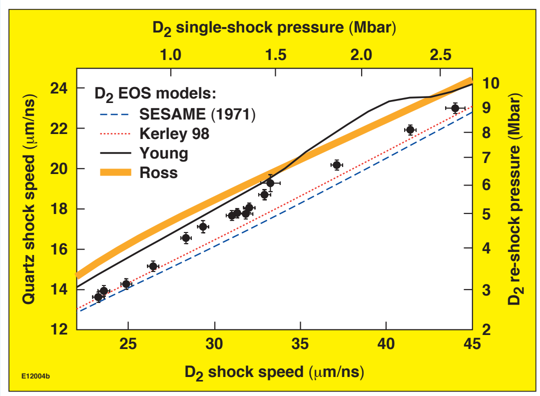

Figure 2. Double-shock EOS data for fluid deuterium obtained using an α-quartz anvil (dark circles with error bars) compared to various models.

OMEGA Operations Summary: In October, OMEGA conducted 124 target shots distributed as follows: 6 shots were taken for LANL, 62 for LLNL, and 55 for LLE. The LLE allocation included shots for ISE, CRYO, SSP, and DDI. The high precision and stability of the OMEGA facility are partly reflected in Fig. 3, which compares the actual on-target energy and requested energy for each of the 124 target shots taken on the facility in October. Even though a large range of energy was requested (40 J to 23,000 J) and a large variety of pulse shapes were requested and produced, the average ratio of actual energy to requested energy achieved was 0.984±0.044 for this set of 124 shots.

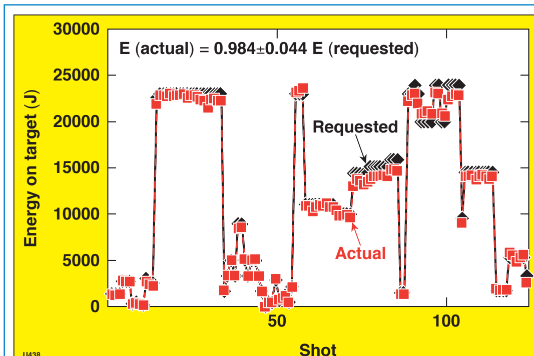

Figure 3. Record of requested and actual on-target energy for OMEGA shots in October 2004.

1. T. R. Boehly *et al.*, Phys. Plasmas **11**, L49 (2004) and LLE Review **96**, 220, NTIS Document No. DOE/SF/19460-509 (2003). Copies of the LLE Review may be obtained from the NTIS, Springfield, VA 22161.
2. A. N. Mostovych *et al.*, Phys. Rev. Lett. **85**, 3870 (2000).

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